Directions: Welcome to the Open Physics topic test! The following conventions are to be used:

- *The frame of refrence for any problem is assumed to be inertial*
- *Positive work is defined as work done on a system by the environment*
- *Current is conventional: the direction positive charge would drift*
- *All circuit components are ideal unless otherwise stated*
- *All thermal expansion effects are negligible*

And, most importantly, ***for the duration of this test, let*** $g = 10m/s^2$. *Good luck!*

1. Andy throws a ball upwards with an initial velocity of 10 m/s. How long will Andy have to wait for the ball to reach his hand again?

   A. 1 s B. 2 s C. 4 s D. 8 s E. NOTA

2. A block of mass 1 kg is initially at rest on a 30-degree inclined plane with coefficient of kinetic friction of $\frac{\sqrt{3}}{5}$. How far will the block travel in 5 seconds? Assume the coefficient of static friction is 0.

   A. $\frac{125}{2}$ m B. $\frac{75}{2}$ m C. 50 m D. 25 m E. NOTA

3. A lump of clay of mass 3 kg moving at 2 m/s to the left collides perfectly inelastically with a ball of mass 7 kg moving to the right at 8 m/s. After the collision, what is the velocity of the resulting object, assuming right is positive?

   A. 5 m/s B. 6.2 m/s C. −5 m/s D. −6.2 m/s E. NOTA

4. An ideal spring has its equilibrium point at x = 0. If it takes 6 J of work to stretch this spring from x = 1 to x = 2, how much work does it take to stretch it from x = 2 to x = 3?

   A. 6 J B. 9 J C. 10 J D. 12 J E. NOTA

5. Consider an ideal gas with pressure and volume given by (P, V) in atm and m^3 for the following three states: A (1, 1), B (1, 4), C (3, 3). How much work is done on the gas by the environment in the cycle ABCA?

   A. 3 J B. 6 J C. −3 J D. −6 J E. NOTA

6. A circuit consists of a 9 V battery and 9 resistors of 9 Ω each wired in parallel. Find the current through the battery.

   A. $\frac{1}{3}$ A B. 1 A C. 3 A D. 9 A E. NOTA

7. A circuit consists of n resistors wired in series with a 5 V battery. Find the current in each resistor, if R_i is the resistance of the i-th resistor in the series, and the following holds true:

$$\sum_{i=1}^{n} R_i = 10\,\Omega$$

A. .02 A B. .5 A C. 2 A D. 50 A E. NOTA

8. Bryan finds himself on a ladder parallel to the y-axis, floating in space. As Bryan begins to climb the ladder in the positive y direction, which of the following describes the y-coordinate of the center of mass of the Bryan-ladder system?

A. Increasing B. Constant C. Decreasing D. Can't Tell E. NOTA

9. Two blocks of mass 2 kg and 4 kg respectively are tied together by a string, and the string is then draped over an ideal pulley such that when one block is pulled down, the other rises, and vice versa, forming an Atwood machine. Find the tension in the string.

A. 20 N B. 60 N C. $\frac{80}{3}$ N D. $\frac{40}{3}$ N E. NOTA

10. An oscillating spring with an angular frequency of $\omega = 2\,\text{Hz}$ has a block attached to it. Given the block goes a maximum of 5 m and no further from the spring's equilibrium in each oscillation, find the maximum speed of the block during any given oscillation.

A. .1 m/s B. .4 m/s C. 2.5 m/s D. 10 m/s E. NOTA

11. DZ is staring down at a loop of wire on his desk. Using his magnetic abilities, he begins to increase the magnetic field downwards into the loop at a linear rate. From DZ's perspective, which of the following are correct?

I. The induced current is clockwise

II. The magnetic field generated by the induced current is in a direction opposite to the field exerted by DZ

A. I and II B. I only C. II only D. Neither E. NOTA

12. A hoop with radius 1m and mass 10 kg is spinning about its central axis at 2 rad/s. If a tangential force of 5 N is applied to the edge of the disc to slow it down, for long does the disc remain spinning?

A. 2 s B. 4 s C. 5 s D. 8 s E. NOTA

13. A cup of ice water sits outside on a hot summer day. As the ice melts, which of the following describes the height of the water level in the cup?

A. Increasing B. Constant C. Decreasing D. Can't Tell E. NOTA

14. A 100 m long rope with a linear mass density of 2 kg/m is hanging from a building. During a workout routine, Konwoo grabs the rope by its middle and pulls it straight up to be even with the top of the rope. If Konwoo's biceps grow by 1 mm for every kilo-joule of work he does, by how much did Konwoo's biceps grow?

    A. 12.5 mm B. 50 mm C. 62.5 mm D. 100 mm E. NOTA

15. Yared, a sphere with radius r, angular velocity ω, and linear velocity v (all positive) is rolling and slipping on a surface. Given that ω is decreasing, which of the following is true?

    A. $v < r\omega$ B. $v = r\omega$ C. $v > r\omega$ D. Can't tell E. NOTA

16. A balloon is filled with air and submerged underwater to depth $d > 1$ m below the surface such that it is neutrally buoyant. A small eddy current causes the balloon to move slightly deeper. Which of the following describes the depth of the balloon right after this downwards movement (Increasing depth would be moving downwards)?

    A. Increasing B. Constant C. Decreasing D. Can't Tell E. NOTA

17. A ramp of mass 4 kg is sitting on a table, and a sphere of mass 2 kg and radius 1 m is sitting with its center 4 m above the table on the ramp. *All* surfaces are frictionless. The system is initially at rest, but the ball and ramp will start to move due to gravity. The ramp is curved such that once the ball reaches the table, it is only moving parallel to the table (no vertical velocity). How fast is the ball moving at that time?

    A. $\sqrt{10}$ m/s B. $2\sqrt{10}$ m/s C. $3\sqrt{10}$ m/s D. $4\sqrt{10}$ m/s E. NOTA

18. A ball of mass 10kg has an initial velocity vector of $(8, 0)$. After a 1 second collision with a rigid wall, its velocity becomes (0, 6). What is the average magnitude of force the ball exerts on the wall during the collision?

    A. 10 N B. 20 N C. 100 N D. 200 N E. NOTA

For the next three questions, consider the scenario in which Jeffrey is driving his Honda Civic in a circle of radius 5 m, where the coefficients of static and kinetic friction between his wheels and the ground are both .5. Jeffrey drives as fast as he can while still maintaining the circle, and never turns the steering wheel from this path.

19. How fast is Jeffrey going?

    A. 2 m/s B. 5 m/s C. 10 m/s D. $10\sqrt{2}$ m/s E. NOTA

20. If Jeffrey were to encounter an oil slick, the coefficients of friction would be reduced by 5%. Which of the following would describe Jeffrey's distance from the center of his original circular path right after contacting the oil slick?

    A. Increasing B. Constant C. Decreasing D. Can't Tell E. NOTA

21. Finally, if Jeffrey were to encounter a patch of ice, the coefficient of kinetic friction would be reduced by 5%, while the coefficient of static friction would remain the same. Which of the following would describe Jeffrey's distance from the center of his original circular path right after contacting the patch of ice?

    A. Increasing B. Constant C. Decreasing D. Can't Tell E. NOTA

22. A firework of mass 6 kg is launched from the point $(-6, 0, 0)$ such that at time t for $0 < t < 6$ its position is the point $(-6 + 4t, 0, 9t - t^2)$. At t = 6, the firework explodes into three pieces of equal mass that land in the x-y plane. If one piece lands at $(20, 5, 0)$ and another lands at $(25, -10, 0)$, at what point does the third piece land?

    A. $(-55, 5, 0)$ B. $(45, 5, 0)$ C. $(30, 0, 0)$ D. $(-55, -5, 0)$ E. NOTA

23. A .5 m thick metal disc with a radius of 5 m has a hole in the middle with radius 1 m. The mass of this object is 12 kg and the metal the disc is made of has a specific heat of 2 J/kg*K. An axle is fit through the hole in the middle and the disc is given an initial angular velocity of 6 rad/s. Due to friction with the axle, the disc eventually slows to a stop as its rotational kinetic energy is lost as heat. Assuming all of this heat is transferred uniformly to the disc and the disc is initially at 300 K, at what temperature is the disc when it stops?

    A. 415 K B. 416 K C. 417 K D. 418 K E. NOTA

For the next two questions, consider an ideal massless spring with length 2 m and spring constant $k = 1$, which has 1 kg masses attached to each end and is floating in space. The spring is stretched and given an angular velocity of 1 rad/sec such that during rotation, the spring remains a constant length.

24. What is the angular momentum of the rotating spring-mass system?

    A. $1\,\text{kg}\,\text{m}^2/\text{s}$ B. $2\,\text{kg}\,\text{m}^2/\text{s}$ C. $4\,\text{kg}\,\text{m}^2/\text{s}$ D. $8\,\text{kg}\,\text{m}^2/\text{s}$ E. NOTA

25. The rotating spring-mass system is magically and instantly transported to a non-vacuum atmosphere, where the masses now face a non-negligible air resistance (and no other additional forces). Right after this happens, which of the following describes the length of the spring?

    A. Increasing B. Constant C. Decreasing D. Can't Tell E. NOTA

26. What is the rotational inertia about an axis through the center and normal to a square of mass m and side length L? (Hint: The inertia about one of its sides is $\frac{1}{3}mL^2$)

    A. $\frac{1}{24}mL^2$ B. $\frac{1}{12}mL^2$ C. $\frac{1}{6}mL^2$ D. $\frac{1}{3}mL^2$ E. NOTA

27. For an insulating cube with uniform charge density ρ and side length s, the electric potential at the center of the cube is given by $V = c\rho s^2$ for some constant c. Find the electric potential at one of the corners of the same cube.

    A. $c\rho s^2$ B. $\frac{1}{2}c\rho s^2$ C. $\frac{1}{3}c\rho s^2$ D. $\frac{1}{4}c\rho s^2$ E. NOTA

When playing professional billiards, the spin imparted to the cue ball when struck is of utmost importance. For the next two questions, consider a situation in which Marc is trying to hit the cue ball into the 8-ball to beat Alex, but wants to show off, so he tries to also pocket the cue ball after the 8-ball. The center of the cue ball is 1.7 m from the center of the 8-ball, and the center of the 8-ball is .8 m from the edge of the pocket. The shot is perfectly straight. The pool balls all have radius .1 m and mass 1 kg with uniform density, and are perfectly spherical ($I = \frac{2}{5}mr^2$). The pool table has static and kinetic coefficients of friction of .1. A ball will go in the pocket once its center passes the edge. Marc will hit the cue ball such that its linear velocity immediately after impact is 1 m/s towards the 8-ball. Assume that once the cue ball hits the 8-ball, its linear momentum is completely and instantly transferred to the 8-ball, and its angular momentum is unaffected.

28. The amount of topspin (i.e. angular velocity) ω that Marc must impart on the cue ball while hitting it to sink it after the 8-ball in a finite amount of time follows $\omega > \omega_{min}$. What is the value of ω_{min}?

    A. 10 rad/s B. 20 rad/s C. 25 rad/s D. 50 rad/s E. NOTA

29. The amount of topspin (i.e. angular velocity) ω that Marc must impart on the cue ball while hitting it to sink it after the 8-ball, *within* 2.5 *seconds of hitting the cue ball*, follows $\omega > \omega_{min}$. What is the value of ω_{min}?

    A. 40 rad/s B. 60 rad/s C. 95 rad/s D. 130 rad/s E. NOTA

30. Which of the following is equivalent to 1 V?

    A. $1\,\frac{\mathrm{m}}{\mathrm{s^3C^2}}$ B. $1\,\frac{\mathrm{m^2kg}}{\mathrm{sC}}$ C. $1\,\frac{\mathrm{m^2kg}}{\mathrm{s^3C}}$ D. $1\,\frac{\mathrm{m^2kg}}{\mathrm{s^2C}}$ E. NOTA